EIC Detector R&D Progress Report
Reporting Period: December 2012 to May 2013

Project Name: A pre-shower detector for forward electromagnetic calorimeters

Project Leader: Sergey Kuleshov

Date: May 17, 2013

Past

What was planned for this reporting period?

Administrative:
To begin the flow of funds for the project. As of the December progress report, no external funds were yet available, due to a combination of factors. We had spent funds from our institution at the level of approximately $10k, in addition to the contribution of the scintillator crystals and manpower for design efforts and machining.

Technical:
1) To substantially advance the design of the mechanical support for the crystals and fiber readout.

2) To complete the measurement of the attenuation length for one crystal. Values for the attenuation length for this crystal vary in the literature by over an order of magnitude.

3) To substantially advance the design of the electronics for the readout of the MPPCs.
4) To place an order for the MPPCs, which is a long-lead item.

5) To begin implementation of the preshower calorimeter geometry into a GEANT4 simulation program.

What was achieved?

Administrative:
We have hired a new laboratory manager who will be in charge of this project, Alison Sherman. The funds managed by BNL became available to us in early May 2013, including all delays related to our university.

Technical:
1) We substantially advanced the design of the mechanical support for the crystals and fiber readout. This design was implemented in the 3D CAD software SolidWorks. The design is essentially complete and is illustrated in figures 1 - 10. Beyond design, we have begun fabrication of the mechanical components. These are illustrated in figures 11 - 15. No design problems have been found thus far. However, polishing of the small lightguides has required us to develop new fixtures, since they are too small to hold by hand when polishing (unlike our previous polishing projects).

2) We have made a measurement of the attenuation length for a single crystal, using the gamma tagging device described in the December 2012 report. For these measurements we have used three different covering methods - no wrap, aluminum foil wrap, and teflon wrap. The three

wrapping methods did not yield substantially different results. Plots of the signal size as a function of distance are shown in Fig. 16, and Fig. 17 shows the signal peak that was used for the measurements using coincidence-tagged gammas. The few-percent variations across the crystal indicate that the light attenuation is a small effect, and therefore that the attenuation length is many times the length of the crystal.

3) The circuit diagram planned for use with the MPPCs is shown in Fig. 18. This design is based on our experience with a number of different types of SiPM technology. It consist of the usual polarization circuit, followed by a low input impedance, high output impedance voltage amplifier using a PNP fast transistor, then a high-pass filter and a voltage buffer to adapt impedance with a QDC. This is the single-channel design and will be one of the 25 channels incorporated on final PCB. The final PCB will also include an adder circuit to build the trigger signal. The input to this adder will come from the pin "to trigger sum" seen on the picture and is a common inverting adder amplifier. The board on which the MPPCs is mounted is planned to be implemented in a 3-layer board. These boards have already been ordered and will go into production soon.

4) The MPPCs have recently been ordered from Hamamatsu.

5) We have begun the simulation of the calorimeter. We have been in contact with the person in charge of the EIC simulation to try to keep consistent with the main thrust. We have simulations of the individual crystals as well as of the array overall. These are at an early stage but progress is visible. In Fig. 22 is shown the simulated single-crystal response to collimated 511 keV gamma rays. This simulation is intended to replicate the experimental measurements with the collimated gamma tagger. In Fig. 23 is shown the crystal array as implemented in GEANT4, including the fiber lightguides and the MPPCs. In Fig. 24 is shown an electromagnetic shower in the array, showing optical light propagation through the crystals as well as through the fiber lightguides. Fig. 25 shows the preshower calorimeter in proximity to a larger, deeper calorimeter so that simulations with a combined system can be carried out.

What was not achieved, why not, and what will be done to correct?

We recently discovered that the delivery time for the MPPCs is many months. We cannot speed this up, but we can try to progress on all other fronts while waiting for these.

Future

What is planned for the coming months and beyond? How, if at all, is this planning different from the original plan?

1) To complete all aspects of the mechanical design.

2) To complete the production of the initial design of the mechanical support.

3) To finish the design of the test board and order one or more boards from a production company. To stuff at least one board for tests.

4) To receive the MPPCs and install them.

5) To complete and validate realistic simulations of the individual crystals and the array for simple inputs. To lay the groundwork for more realistic event simulations and for preshower calorimeter + full calorimeter simulations.

The order of events is the same as the original plan, however there have been some setbacks due to delayed funding as well as delayed availability of facilities and manpower.

What are critical issues?

1) How small can we make the gaps between the crystals? How uniform are those gaps?
2) Is there unanticipated crosstalk, either electronic or optical?

Additional information:

The team currently working on this project is:

1) Dr. Sergey Kuleshov, physicist, head of detector lab, project leader.

2) Dr. William Brooks, physicist, project coordination

3) Dr. Hayk Hakobyan, physicist, simulation coordination

4) Ms. Alison Sherman, senior administrative specialist, detector lab project manager

5) Mr. Alam Toro, electronics engineer, electronics design

6) Mr. Juan “Iñaki” Vega, mechanical engineer, mechanical design

7) Mr. Juan Pavez, Informatics PhD student, GEANT4 simulation

8) Mr. Esteban Zambrano, electronics engineering undergraduate student, single-crystal measurements and GEANT4 simulation (student thesis)

9) Mr. Elias Rozas, CNC technician, CNC mill programming and operation

10) Mr. Pavlo Bazalyeyev Pavlo, expert technician, mechanical fabrication

This is our highest priority laboratory project now that we have completed our two previous major projects (fabrication of 4000 lightguides, characterization of 2800 16-cell MPPC devices).

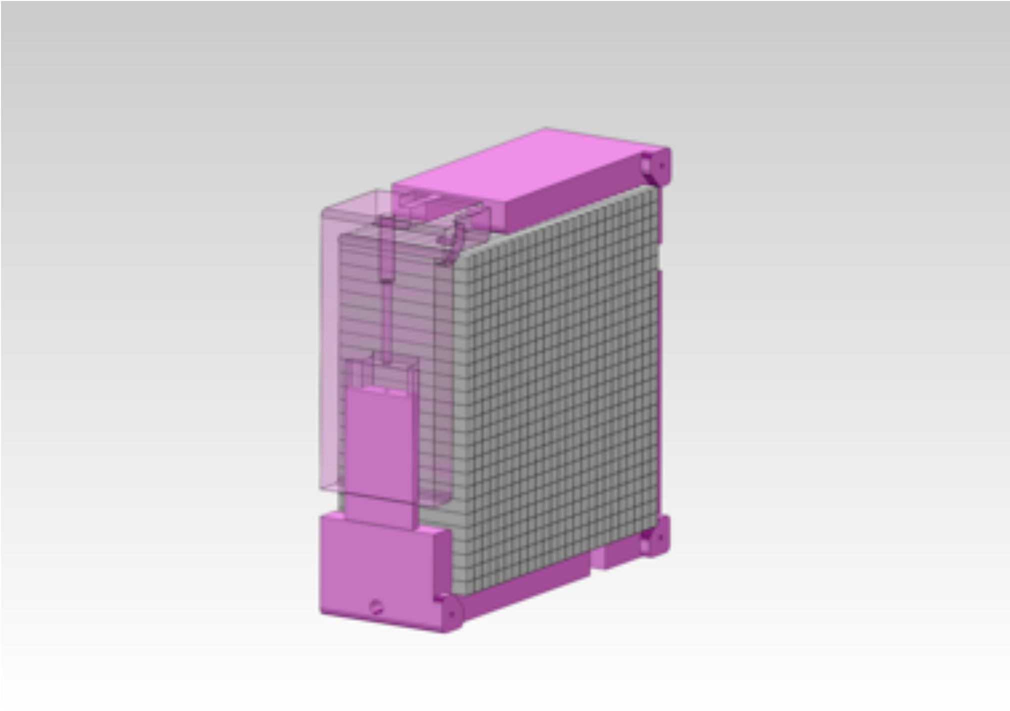

Figure 1. View of the crystal assembly together with its support structure and tensioning scheme.

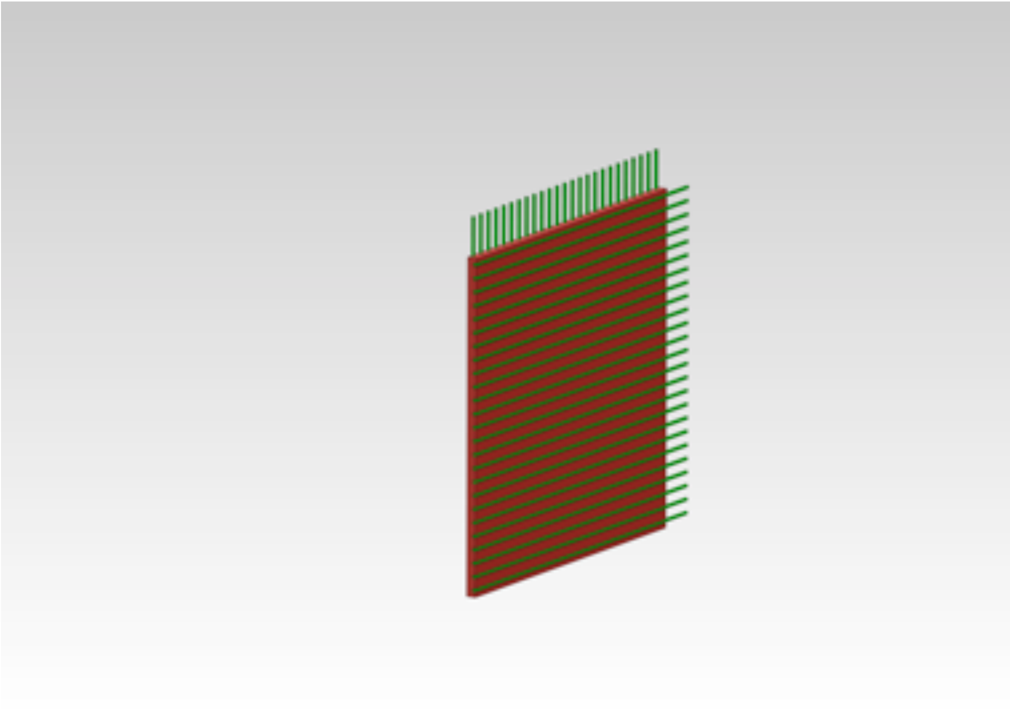

Figure 2. View of the fiber positioning plate together with the x and y fibers.

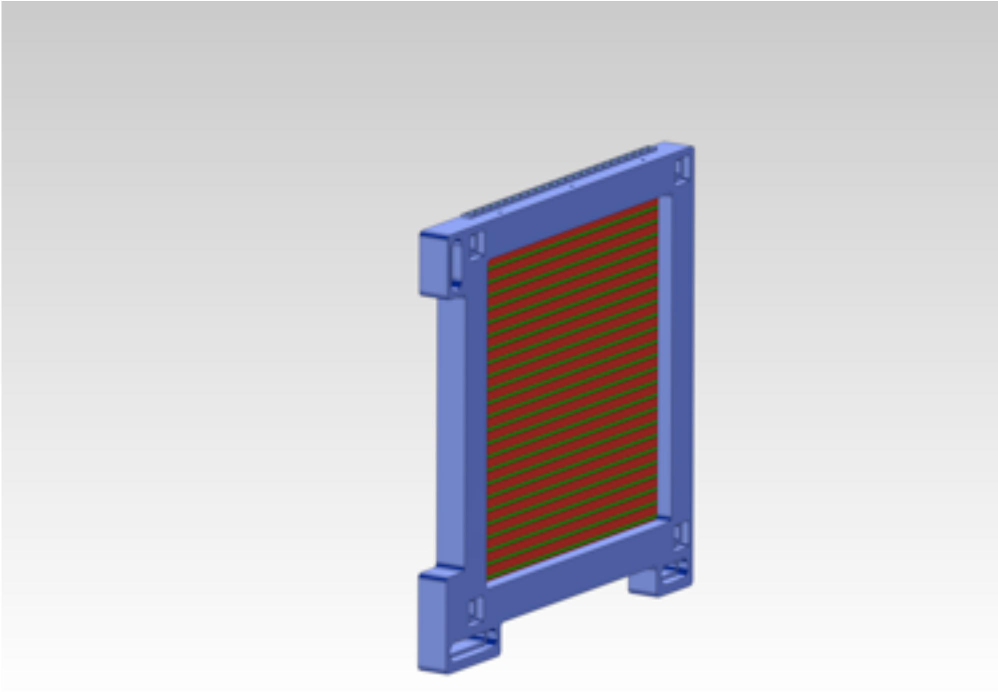

Figure 3. Fiber positioning plate and x and y fibers in the fiber mounting assembly shown in blue. The fiber mounting assembly is used to securely position the fibers against the crystal array.

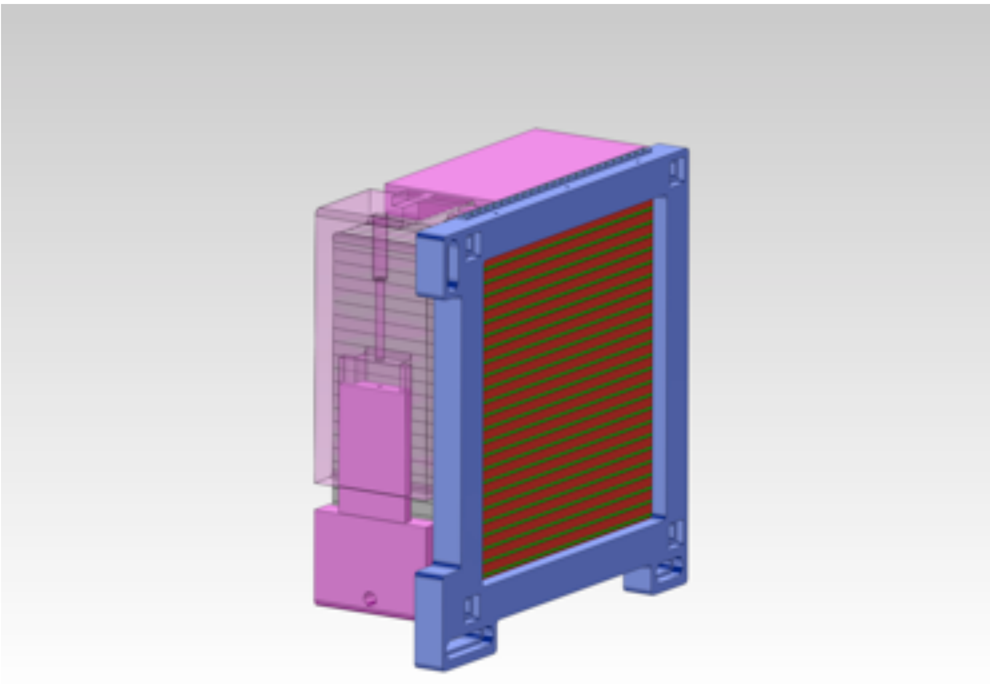

Figure 4. Fiber mounting assembly mounted in proximity to the crystal array.

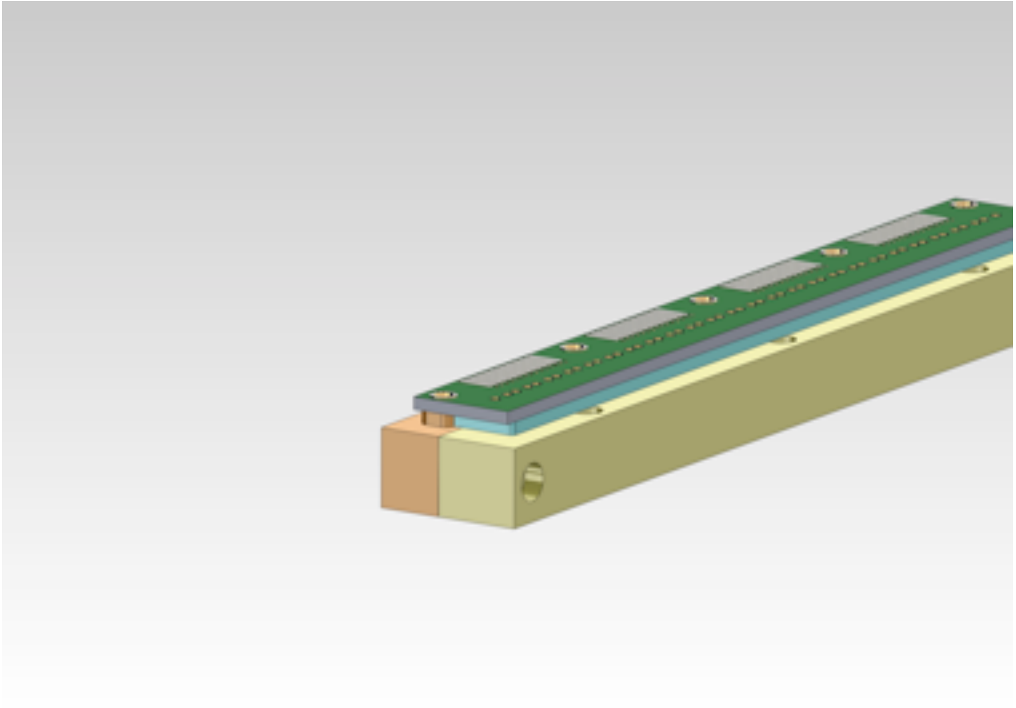

Figure 5. Circuit board for the MPPCs with mechanical mounting block.

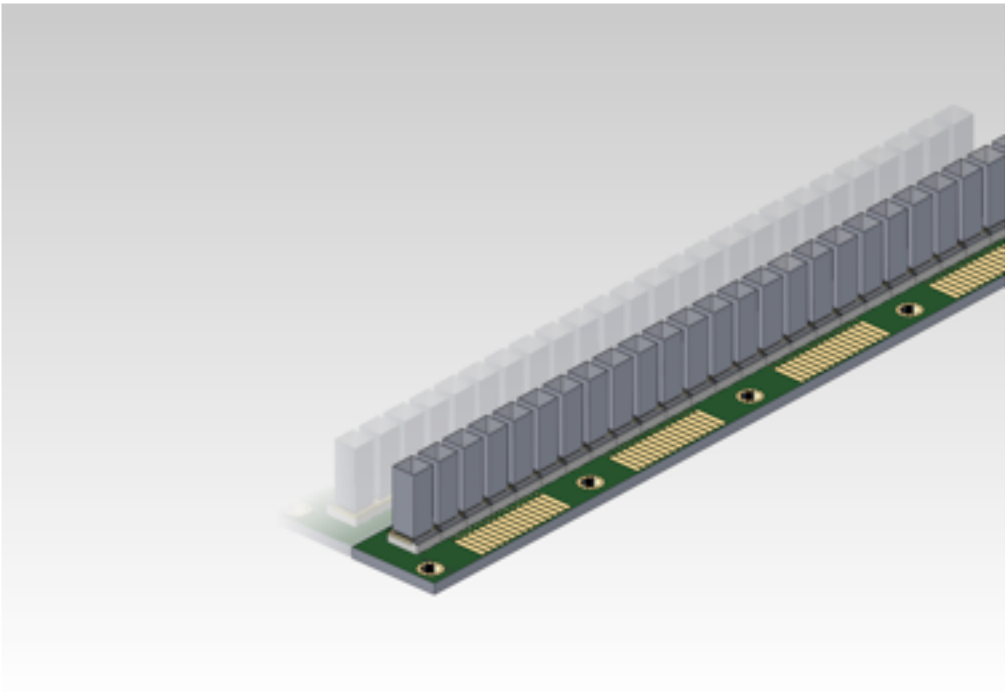

Figure 6. Circuit board with mounted MPPCs and light guides.

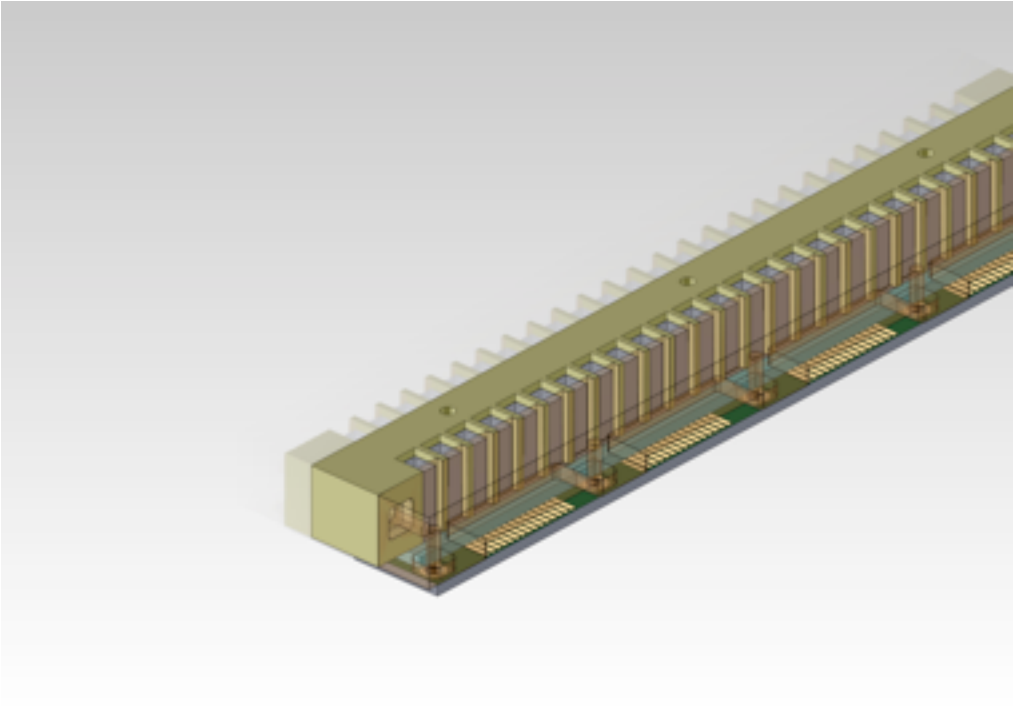

Figure 7. Circuit board with mounted MPPCs, light guides, and light isolation fixture.

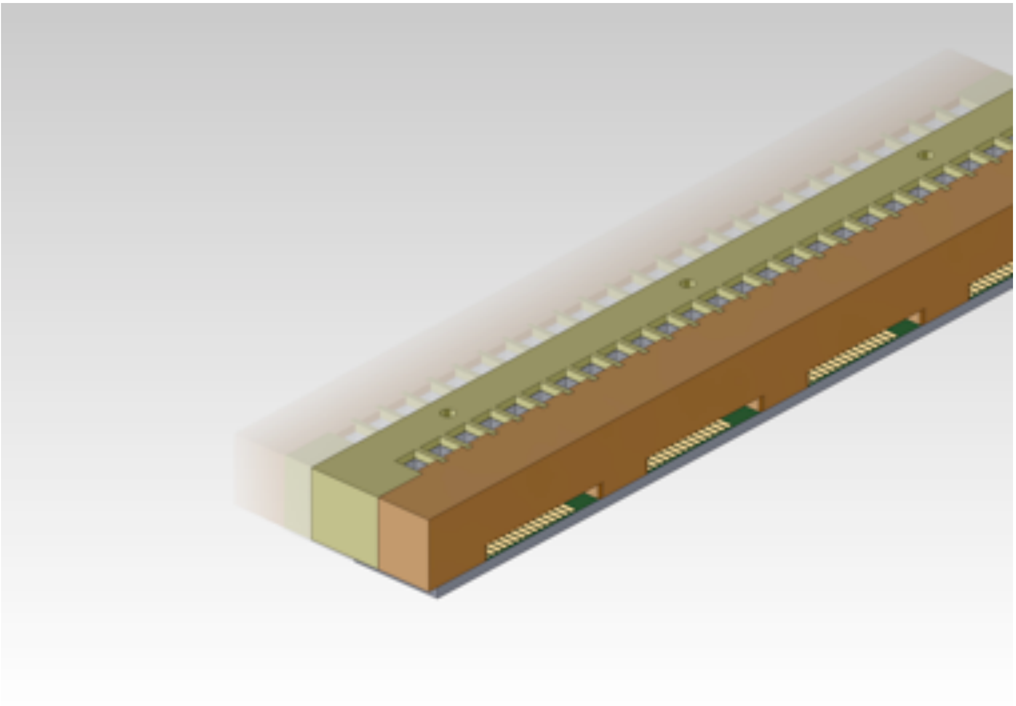

Figure 8. Final MPPC and lightguide assembly.

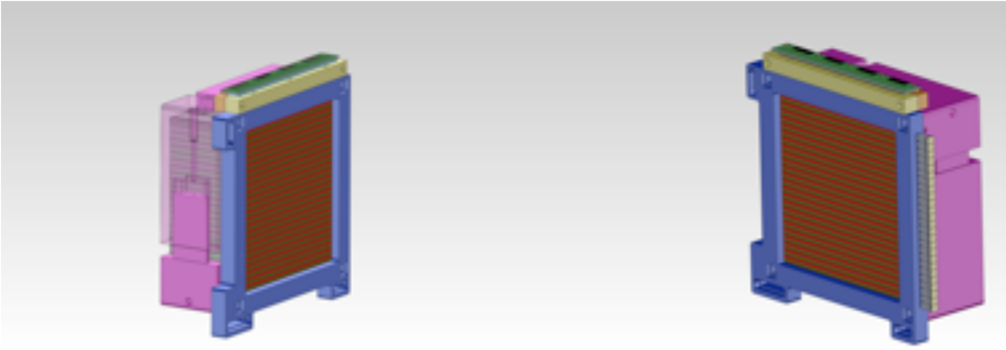

Figure 9. Fiber mounting assembly mounted in proximity to the crystal array with MPPC and lightguide assembly mounted on top. Lightguides and MPPCs are shown protruding on the right panel along the vertical edge.

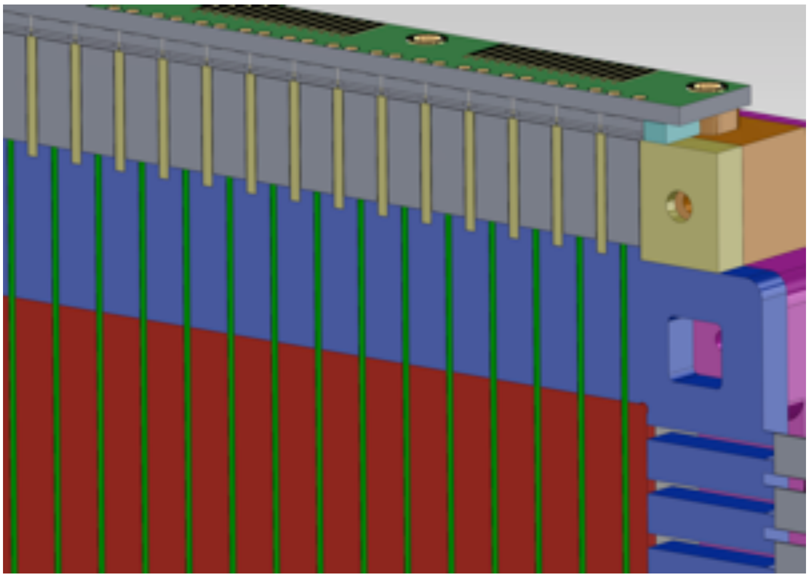

Figure 10. Detail view showing the interface region between the fibers and the light guides.

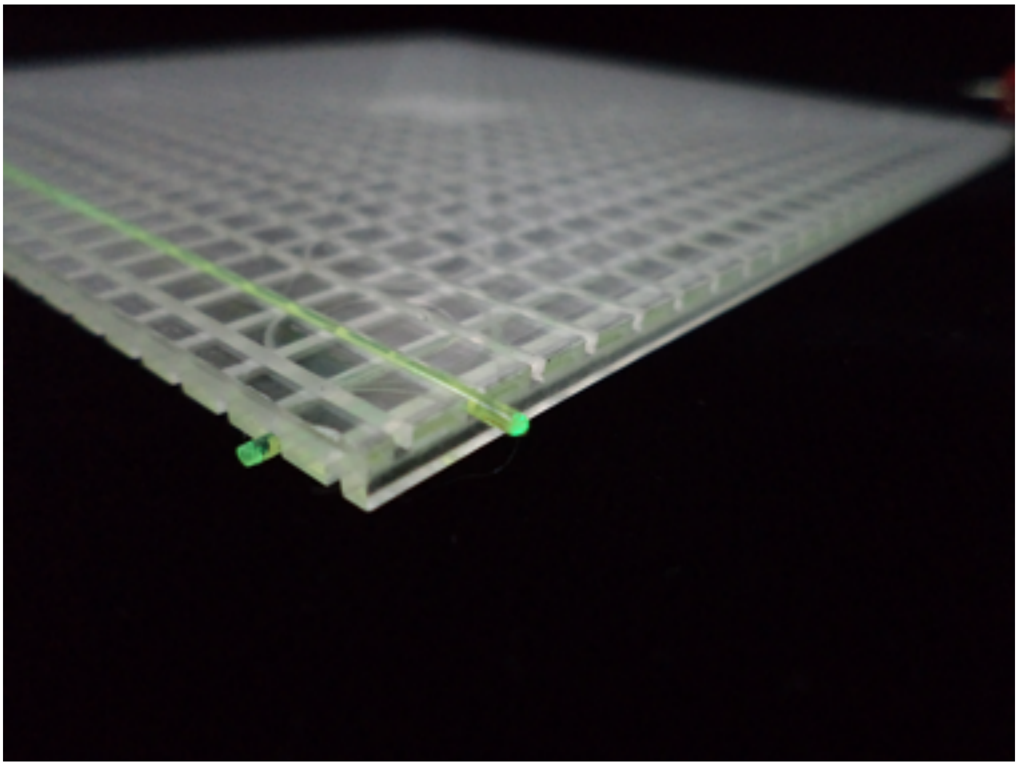

Figure 11. Fiber positioning plate as machined, with one x fiber and one y fiber.

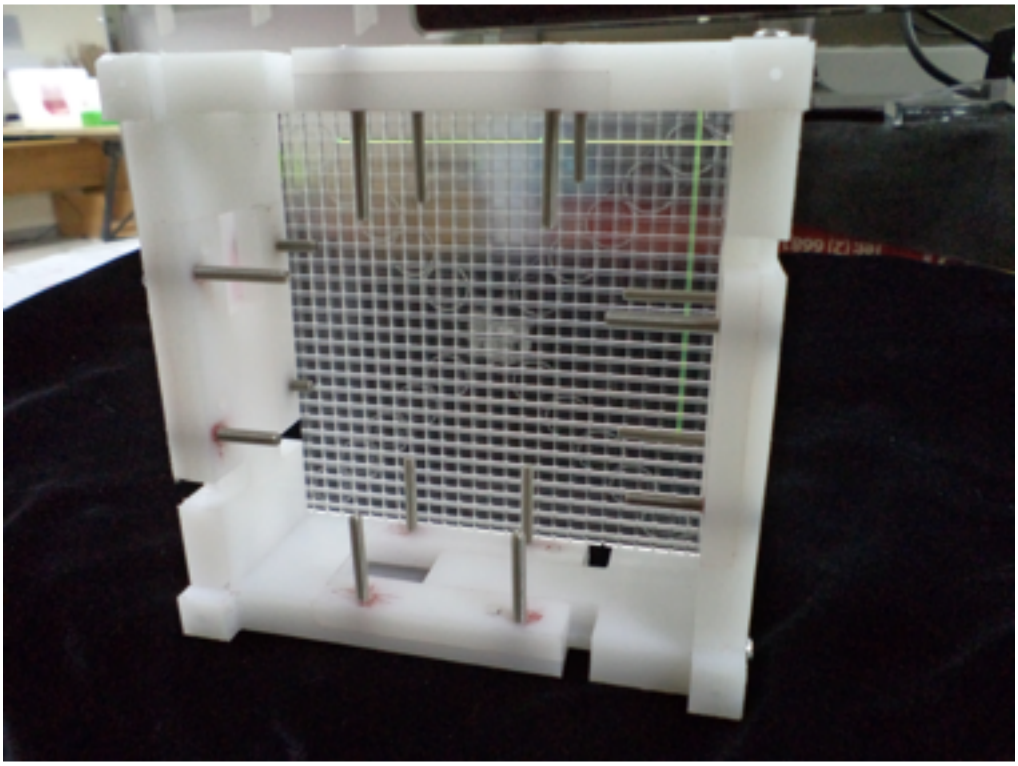

Figure 12. Fiber positioning plate, with two fibers installed, attached to the crystal array housing. (The bolts shown are temporary; shorter bolts will ultimately be used, since these protrude into the volume where the crystals will be located.)

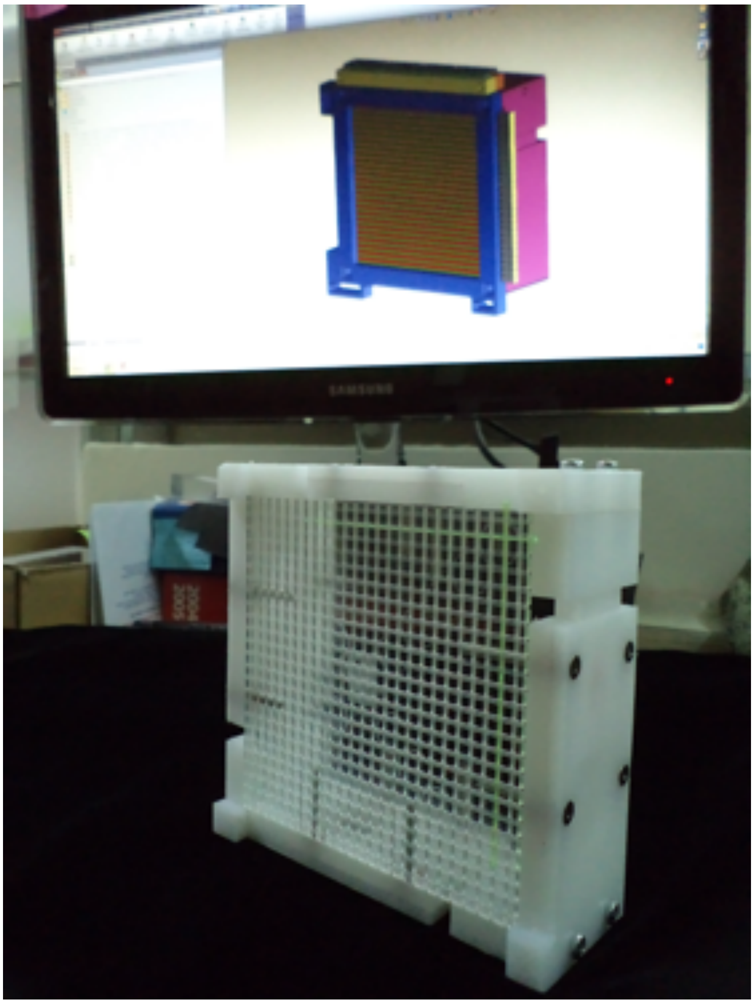

Figure 13. Rear view of the assembly, with two fibers in place.

Figure 14. Detail view of the overlap region of the fibers.

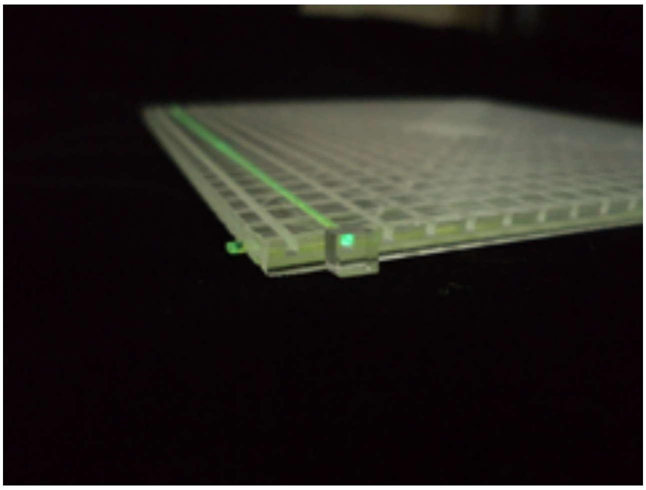

Figure 15. Detail view of the readout end of one fiber, showing a prototype lightguide (the small block of plastic at the end of the fiber).

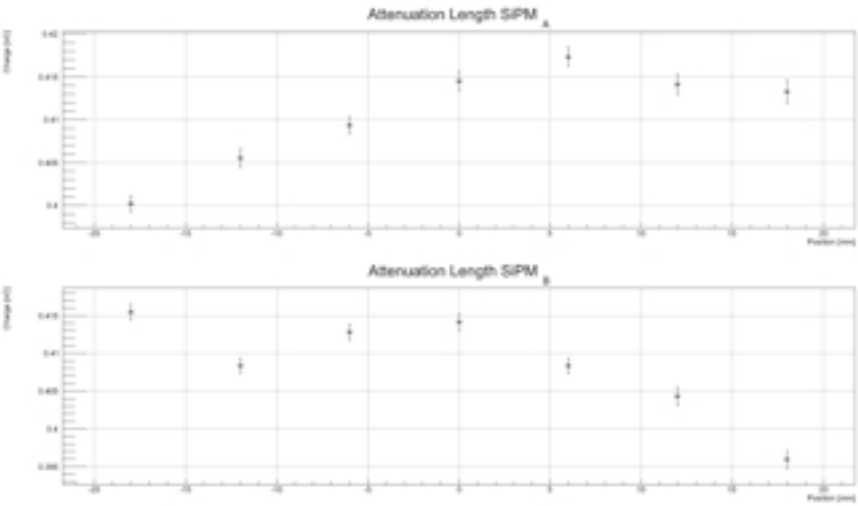

Figure 16. Light vs. position for the SiPMs on each side of a single crystal. For this measurement the crystal was wrapped in Teflon, however, wrapping with aluminum foil, and no wrapping, at all produced similar results.

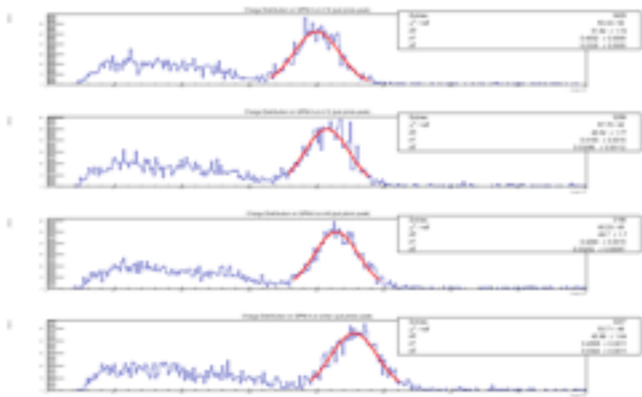

Figure 17. Typical fits for the tagged photopeak amplitude for different positions along the crystal, used in the light attenuation measurement of a single crystal.

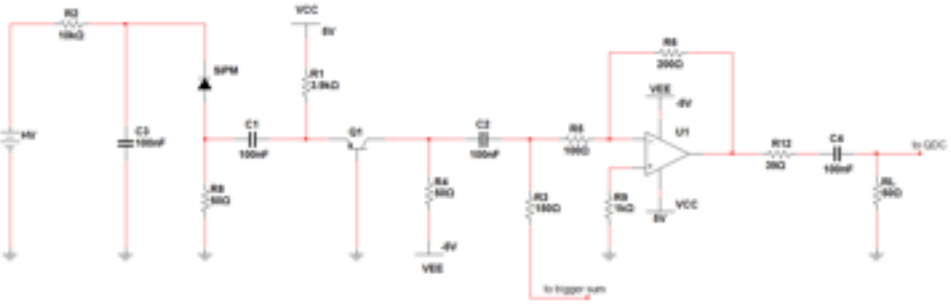

Figure 18. Circuit for amplifying and conditioning the MPPC pulse.

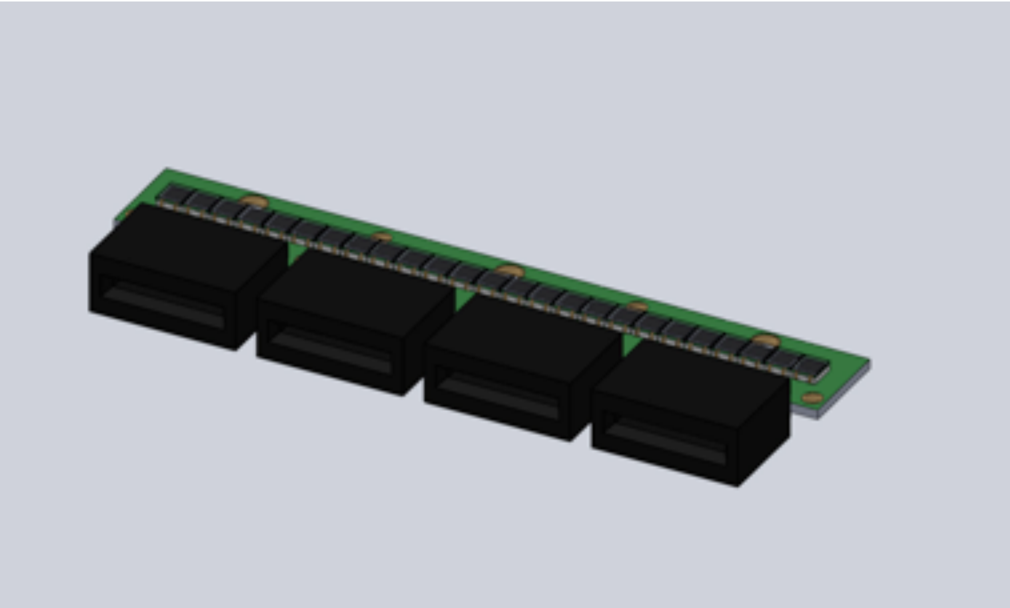

Figure 19. Design for circuit board for 25 MPPCs, with connector.

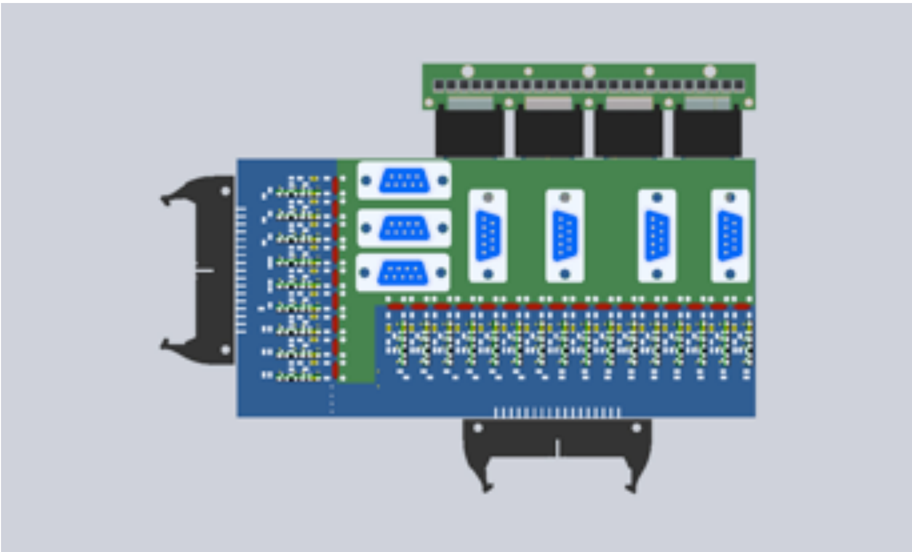

Figure 20. Test board for 25 MPPCs. The MPPC board is visible on the upper right.

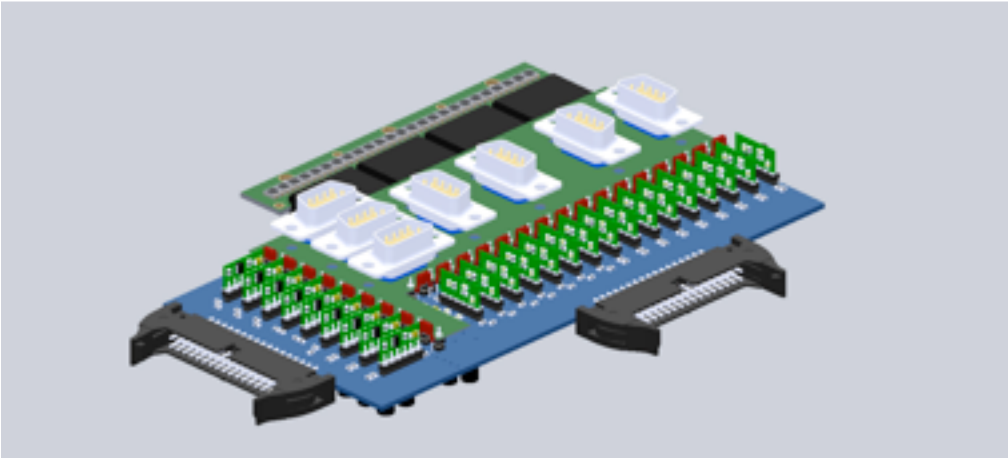

Figure 21. A 3-D view of the test board attached to the MPPC board.

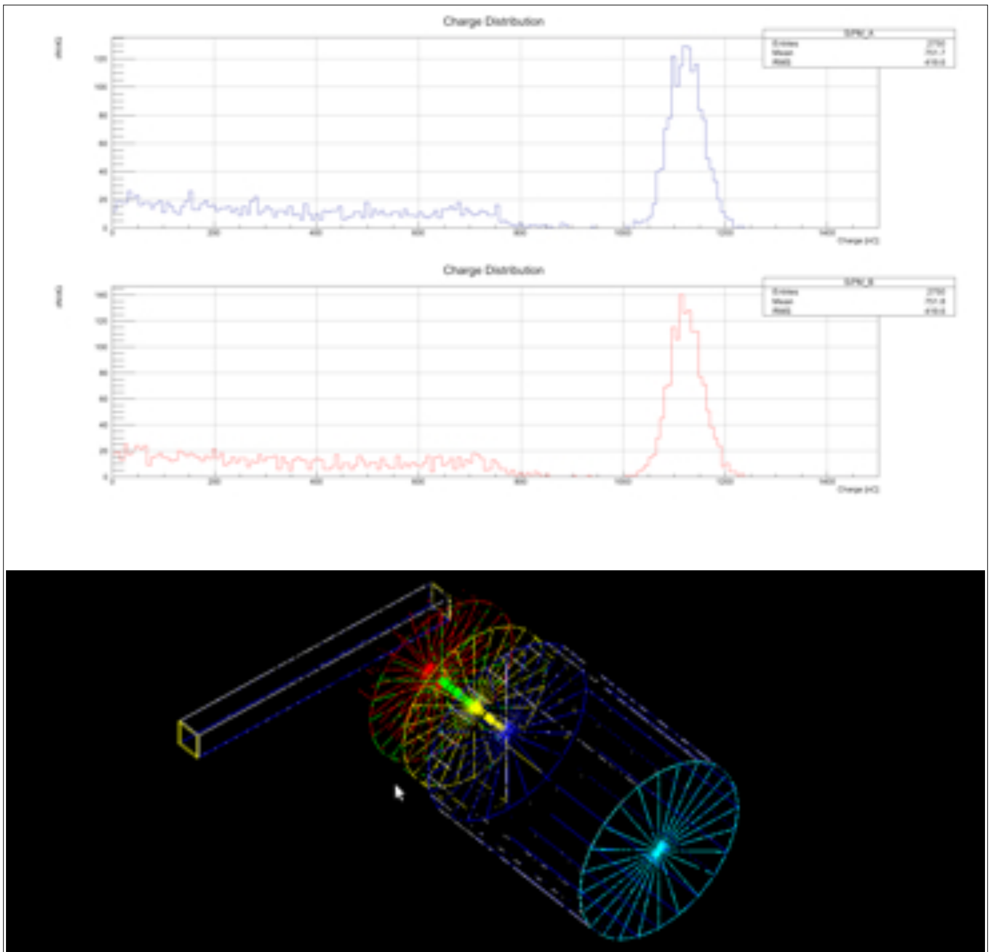

Figure 22. (upper) Simulated single-crystal response to collimated 511 keV gamma rays using GEANT4, replicating the experimental measurements with the collimated gamma tagger. (lower) Gamma tagger and single crystal as implemented in GEANT4.

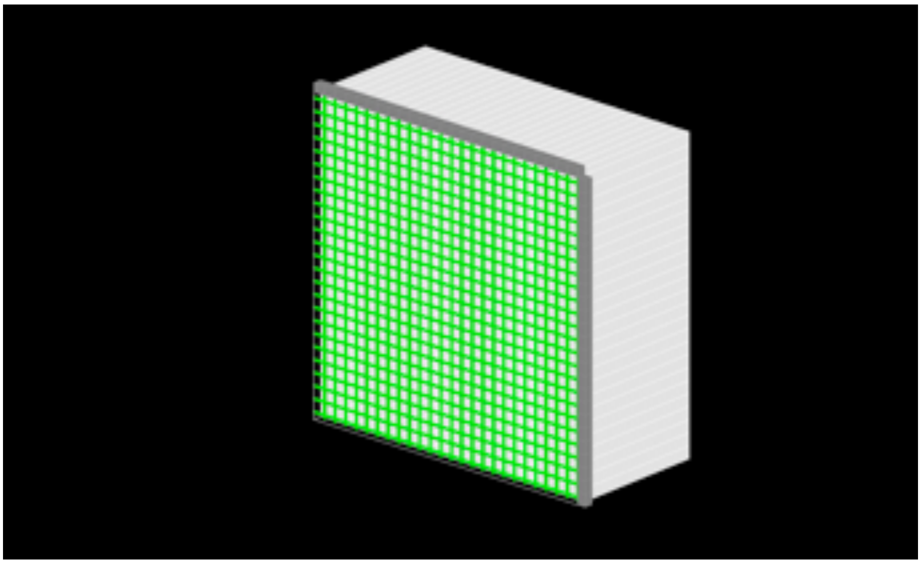

Figure 23. Crystal array geometry as implemented in GEANT4, including the fiber lightguides and MPPCs.

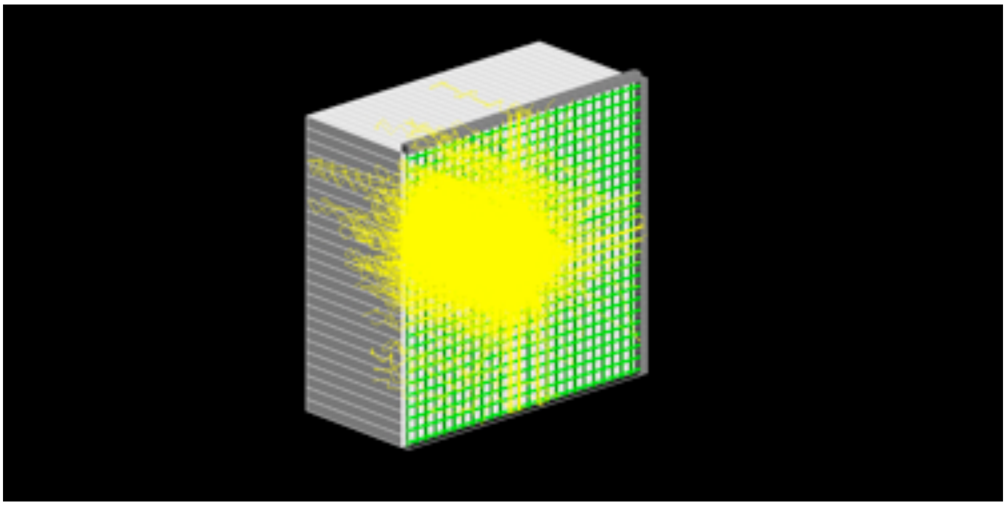

Figure 24. GEANT4 simulation of an electromagnetic shower in the array, including optical light propagation through the crystals and through the fiber lightguides.

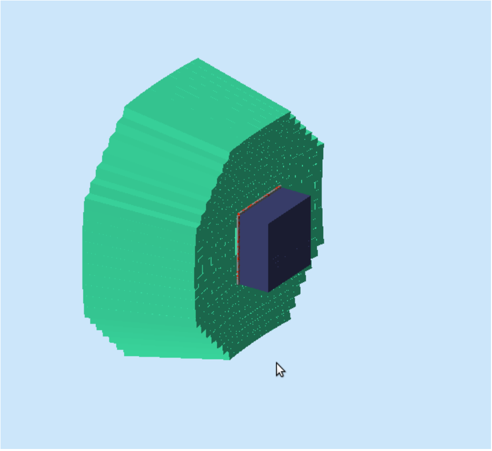

Figure 25. The preshower calorimeter in blue positioned in front of a larger segmented calorimeter in green in a GEANT4 simulation.